Indoor air quality — the NIOSH experience

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Introduction

Health complaints associated with poor indoor air quality have been reported with increasing frequency among office workers over the past 10 years. A number of factors have contributed to this trend, including changes in building design to increase energy efficiency, introduction of new building materials, and increased awareness among workers of potentially toxic exposures in their work and home environments. While some exposures in the indoor environment may have serious implications for the health of the occupants (e.g., radon daughters, asbestos, formaldehyde, pathogenic microorganisms, allergens), the health risks of most indoor air exposures are poorly understood. Nevertheless, office workers who are concerned about a possible problem in their work environment often demand a thorough investigation of the environment and of its potential for health risks. For the investigator, this is commonly a challenging but frustrating experience because of the lack of guidelines and evaluation criteria for the "non-industrial" setting.

The health complaints reported by the occupants of the typical "problem building" are usually diverse and non-specific, and rarely point to an obvious cause. Also, the nature of the problem may be obscured by reports of a variety of serious, but unrelated, medical conditions associated with the office environment.

Appropriate environmental sampling is often quite difficult because of the presence of low levels of many ubiquitous substances. Specific contaminants from sources in the office can be readily measured and quantitated (e.g., ozone from copying machines), but more often very low levels of a variety of chemicals are detected. Such sampling results may in one sense be reassuring, but they have limited usefulness when linked with non-specific symptoms. These investigations are often complicated by extensive media coverage, multiple earlier investigations by other groups, and deteriorating labor relations. The "Federal expert" often comes into the picture when, despite much basic work having been done, the situation has reached a "crisis."

This paper will briefly present and review the indoor air quality investigations conducted by the National Institute for Occupational Safety and Health (NIOSH) since the start of the Health Hazard Evaluation Program. These investigations are being presented not as "THE WAY" to evaluate such problems, but, rather, to review our experience and share our insights as we have evolved our approach to these investigations.

Indoor air quality health hazard evaluations

Through December 1983, NIOSH has completed 203 Health Hazard Evaluations involving indoor air quality (IAQ) in a variety of settings (Table I). (This does not include our investigations of asbestos-related problems in office buildings.) Prior to 1978, only six IAQ evaluations were performed; however, since then, the number has increased dramatically. It appears that in the last 2 years, the number of these completed investigations has leveled off, but this change may reflect our handling of many IAQ inquiries by providing written materials and phone consultation, and by the increased capability of state and local health de-

TABLE I
Completed NIOSH Indoor Air Quality Investigations by Year (through December 1983)*

Year	Number Completed	%
Pre-1978	6	3.0
1978	9	4.4
1979	12	5.9
1980	28	13.8
1981	80	39.4
1982	44	21.7
1983	24	11.8
Total	203	

* Does not include 81 currently active projects.

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partments and other groups to handle these evaluations without our assistance.

Most of our evaluations have involved government and private offices (over 75% [see Table II]), educational institutions (14.8%), and health care facilities (9.3%). Given our mandate to evaluate occupational health problems, it is not surprising that NIOSH has not investigated very many residential IAQ problems. Thus, we do not have much experience in evaluating problems which are principally encountered in residential buildings such as exposures to radon daughters or to combustion products.

In reviewing the reports on these evaluations, we have attempted to classify our findings by the type of problem found (Table III). It is of note that nearly half of these investigations have attributed the IAQ problems to inadequate ventilation. Some form of environmental contamination was thought to be the source of the problem in approximately 30%. The source of this contamination was thought to be from inside the building in 17.7% of the investigations, outside the building in 10.3%, and from the building structure in 3.4%. Problems such as hypersensitivity pneumonitis, cigarette smoking, humidity, etc., have accounted for approximately 10% of our evaluations. Finally, in another 10%, the etiology of the IAQ problem has remained unexplained.

In reviewing these results, several factors should be considered. First, over time, NIOSH has not used a standard protocol for conducting these evaluations. Our methods and criteria have changed as we became more familiar with the problem and developed new approaches. Also, some of these investigations were conducted several years ago, leaving only scanty data and a brief report for current review. In the early studies, many of the "unknown" problems may have actually been due to inadequate ventilation, but the reports did not provide enough information to determine this. Thus, there may be considerable misclassification in this list.

TABLE II
Completed NIOSH Indoor Quality Investigations by Building Type (through December 1983)

Type	Number	%
Government and business offices	154	75.9
Schools and colleges	30	14.8
Health care facilities	19	9.3
Total	203	

TABLE III
Completed NIOSH Indoor Air Quality Investigations by Type of Problem (through December 1983)

Problem	Number	Total
Contamination (inside)	36	17.7
Contamination (outside)	21	10.3
Contamination (building fabric)	7	3.4
Inadequate ventilation	98	48.3
Hypersensitivity pneumonitis	6	3.0
Cigarette smoking	4	2.0
Humidity	9	4.4
Noise/illumination	2	1.0
Scabies	1	0.5
Unknown	19	9.4
Total	203	

This listing is also not necessarily representative of the general distribution of indoor air quality problems in offices. Often, NIOSH is requested to conduct an evaluation only after initial attempts to identify the problem have failed or complaints have persisted after initial corrections have been made. Large public-sector agencies use NIOSH as a resource, but managers of smaller offices or office buildings may be unaware of our program. Therefore, these facilities may be underrepresented on our list. Despite these shortcomings, the list does provide an overview of the types of indoor air quality problems encountered in office environments. A brief review of the major types of IAQ problems follows.

Contamination from inside the office environment

This classification (approximately 18%) refers to exposure to a chemical or other toxic agent generated within the office space. Usually the symptoms experienced by the office worker are directly linked to the exposure, but if the exposure is disseminated through the building's ventilation system, localization of the source may be difficult. Examples from Health Hazard Evaluations include exposures to methyl alcohol from spirit duplicators,[11] exposures to methacrylate from copiers,[12]

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and exposures to sulfur dioxide from a heating system.[3] Occasionally, a very specific health effect can aid in the investigation, such as the occurrence of dermatitis from amines used in humidification systems.[4,5] The use of pest control agents, such as chlordane, may also cause persistent problems in office environments.[6,7]

These problems can usually be identified by inspecting the affected office area (e.g., copying machines) and by questioning about other uses of chemicals in the building (e.g., pesticides, humidification agents). Environmental and medical testing appropriate for that chemical can then be conducted.

Contamination from outside the building

This classification (approximately 10%) refers to exposure to a chemical or other toxic substance originating from a source outside the building. Common examples include motor vehicle exhaust either from a parking garage or loading dock entering the building through the intake from the ventilation system.[8,9] Many of these exposures are "presumed" explanations that cannot be documented at the time of the investigation. Although the dispersal of substances through the ventilation system may seem obvious, the complexity of the system may require the use of more sophisticated techniques such as a tracer gas to document the problem.[8] Other outside sources include nearby construction activity which may generate sufficient exhaust fumes, dust, or other contaminants to cause complaints in nearby offices.[10]

A few years ago, NIOSH evaluated a dramatic case of outside contamination of an office building when we discovered a 6-million-gallon underground gasoline spill while investigating irritative symptoms among the office occupants.[11] While this may be viewed as unusual, there is concern about the increasing number of underground gasoline tank leaks.

Contamination from the building fabric

Contamination from the building fabric (approximately 3% of our evaluations) refers to problems from the material used to construct the building. While not included in our list of evaluations, asbestos is obviously a major source of concern about indoor air quality. Other insulating materials are a common source of these problems because of the release of substances such as formaldehyde.[12] Dermatitis due to fibrous glass has also been a common problem, usually after the fibrous glass insulation has been disturbed during some construction activity.[13]

Hypersensitivity pneumonitis

This group (approximately 3% of our evaluations) refers to problems due to a hypersensitivity reaction to microorganisms in the building environment. Although not a common cause of office problems, the potential medical severity of this condition and the difficulties in controlling this problem make it an important cause of office problems. NIOSH's evaluations regarding this problem will be discussed later in this volume.

Inadequate ventilation

By far the largest classification, this group makes up approximately one-half of our completed evaluations. Our determination of inadequate ventilation is commonly made after considering a number of factors, including the absence of other sources of contamination and the presence of only very low levels of contaminants in our environmental sampling results. These, linked to the widespread occurrence of non-specific symptoms such as headaches, eye irritation, and upper respiratory irritation, suggest that an evaluation of the ventilation system may be warranted.

The evaluation of ventilation systems will be discussed later. Our methods range from obtaining specifications on the building ventilation system to detailed air flow measurements. Both approaches can present difficulties. Information on the specifications of the ventilation system is often not readily available from the building operators. Buildings with renovated ventilation system are often very difficult to evaluate because of the piecemeal approach used in such renovation. The ASHRAE guidelines for ventilation are usually used for comparison.[14] While one can question the basis for these guidelines, we have found them useful in evaluating IAQ problems and for recommending corrections where there is a problem because of inadequate ventilation.

The pathogenesis of complaints or symptoms caused by inadequate ventilation is not clear, but certain extreme situations have provided us with some insight into the relationship between such complaints and inadequate ventilation. In 1982,

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we conducted an evaluation at a government office building in Idaho with widespread complaints among the employees. Despite environmental surveys showing no significant contaminant levels, the employees were moved to another building. Our investigators found that the air intake for the building had been covered with plastic one year earlier, to protect the air handling system from airborne debris from Mount St. Helens, and that this cover had never been removed. Removal restored intake of adequate outdoor air to the building and allowed reoccupancy without significant problems.[15] However, in this situation, no environmental measurement indicated that there was a problem. In general, we have not found any environmental measurement to be useful as an indicator of poor ventilation. However, it should be noted that other investigators have found carbon dioxide levels useful for such evaluations.[16,17] Low levels of multiple contaminants are often present in these situations and are currently the best explanation for the occurrence of symptoms. The pattern of contaminants probably varies from building to building, but we do not yet have adequate measurement techniques or adequate knowledge to easily recognize this problem through environmental sampling.

Current evaluation methods

Our current approach to evaluating office environment requests usually begins with a walk-through evaluation by an industrial hygienist. Prior to this, we try to obtain background information on the history of the building design or construction and try to ensure that the building engineer will be present during the investigation. During the initial visit, we obtain a history of complaints among office occupants by interviewing as many as is feasible. This is helpful not only for identifying the type of medical complaints, but also for obtaining a chronology of the problem and ascertaining the time pattern of symptoms (afternoon more than morning, etc.).

Potential sources of contamination are identified during the initial walk-through evaluation. Some will be obvious (e.g., copying machines), while others may be identified only after careful questioning (e.g., pesticide spraying). We also usually inspect the ventilation system for the particular office area and attempt to understand its connection to the system for the entire building. Information on the control of the ventilation system (outdoor air intake relative to temperature, etc.) is also obtained. Some environmental sampling may be conducted if a source of contamination is found or suspected. Some general air monitoring (e.g., organics) may also be conducted, but this is usually more helpful to reassure the occupants that the toxic substances of concern to them are not present in any degree than it is for identification of a problem.

The problem may be resolved during this initial visit, but, in some instances, more extensive environmental sampling, a medical study, a ventilation assessment, or some combination of these may be required. These may be necessary either to better identify the source and extent of the problem or to alleviate the concerns of the affected employees. Once our investigations are complete, our findings and recommendations are communicated to the involved parties.

Future activities in indoor air quality

More research into office ventilation and its effect on background levels of contaminants is necessary to provide better guidelines for evaluating and controlling indoor air quality problems. Because of the nature of these exposures, a variety of governmental agencies and private groups are involved in this research effort. Recently, the Environmental Protection Agency, the Consumer Product Safety Commission, the Department of Energy, the Department of Health and Human Services, the Tennessee Valley Authority, and several other Federal agencies formed a coordinating committee on indoor air quality research. This committee will help to coordinate Federal government indoor air quality research. Already, an inventory of IAQ-related research in the Federal government has been prepared. These agencies are also coordinating the planning of a possible large national survey of indoor air pollution and related health problems.

While much of this effort and related research may seem remote to investigating specific problems in office buildings, they may provide the basis for better guidelines for evaluating indoor air quality and for necessary corrective steps. At the same time, improved methods of assessment are needed to evaluate specific types of problems.

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NIOSH is currently developing better methods for assessing indoor air quality (e.g., microorganism levels, ventilation parameters, etc.). Other groups are working on methods for other types of assessments. Meanwhile, we will continue to evaluate indoor air quality problems and, hopefully, continue to improve our efforts in these assessments.

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